

AN END-TO-END NEAR-EARTH ASTEROID RESOURCE EXPLOITATION PLAN

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Overview

- Exploration Super-phase
 - Prospecting
 - What resources may be available to a particular market?
 - Exploration
 - What resources are available, where are they located, and how are they studied?
 - Evaluation
 - Of the resources/markets studied, which are economic?
- Mining Super-phase
 - Initialization
 - Actions leading up to, and including, pilot operations
 - Industrialization
 - High-risk enlargement of operations after pilot, including making operations profitable
 - Closure
 - How do you close a particular mine operation

An abstract graphic in the top-left corner featuring several overlapping circles and arcs in various shades of gray. One circle is particularly prominent, with a smaller circle inside it, and several thin arcs intersecting the larger shapes.

Exploration Super-phase

Prospecting

- Finding resources available in a new frontier (emphasis on asteroids).
- Asteroids a dispersed resource, unlike planetary bodies.
- Ground-based remote sensing techniques likely to be initially more cost-effective than spacecraft.
 - Same data as spacecraft fly-by.
 - More asteroids observed per dollar.
 - Possibly longer time-scale for observations.
- Mining engineering research to use remote sensing data to simulate conditions and research technology for proper conditions.

Exploration

- Examination in detail of prospected resources (spacecraft).
- Decimation of resource candidates done through analysis of remote sensing data.
- Approximately 5 to 20 ranked candidates
 - Flyby's of low-ranked asteroids for close remote sensing and “pop-off” landers/rovers carrying geochemical instruments.
 - Rendezvous of orbiter/lander/rover complexes for high-ranked asteroids carrying coring equipment.
- Emphasis on geotechnical characterization of asteroid as well as physical/geochemical characterization. Studies and simulations of beneficiation and processing of found resources.
- Markets identified for found resources. Studies and simulations of material transport to market.

Evaluation

- Explicit evaluation on resource-market economics using all data from Prospecting and Exploration stages.
 - Includes possibility of one-to-many mapping for resource-market pairs.
 - Includes possible abandonment plans for current operations, with possible re-start from Prospecting data for another list of candidates.
- This stage is actually run concurrently with Exploration stage.
- Science, engineering, and economic data come together for consideration.

Decision

- Explicit decision as to:
 - Resource to be exploited
 - Market(s) to be serviced
 - Source target asteroid for exploitation specifically identified
- Equated to a Go/No-Go decision as enterprise is put into high gear after this determination.
- Geotechnical abstraction gives way to the pragmatic.
 - How do we drill an asteroid? → How do we drill this asteroid?
 - How do we blast on an asteroid? → How do we blast on this asteroid?
 - How do we reinforce an asteroid? → How do we reinforce this asteroid?
- Mining engineering starts to take precedence over scientific research.
- Proprietary knowledge becomes paramount.
- The end of government underwriting/partnerships?

Mining Super-phase

Initialization

- Focused actions leading up to, and including, pilot operations.
- Probably most expensive stage in lifecycle in terms of investment vs. return.
- Pilot operations
 - Extraction, beneficiation, processing, transportation done on small-scale.
 - Robotic for long-term pilot operations.
 - Manned for short-term pilot operations.
 - Proof-of-concept mining and transport technology.
 - Proof-of-concept market supply.
- Analysis of pilot operations with emphasis on efficiency and economic viability.

Industrialization

- Major increase in scale and efficiency for mining operations (ramp-up).
- Longest and (at long last!) most profitable stage in lifecycle.
- The amount of material mined, processed, and transported enters a balancing act of quantity versus market value.
 - Driven by market forces, not technological achievement.
 - Manual vs. manned vs. automation a fluid decision, may be changing during the stage.

Closure

- No EPA, no BLM (yet), but still need closure plan for mine due to economics.
- Decrease operations to stoppage, equipment disassembly and transport, personnel transfer or furlough.
- Mine is “safed”.
 - Waste contained so as not to be hazard (melt-glass enclosures?).
 - Dependent upon amount of asteroid actually left from mining.

Discussion

- Stages outlined here are not necessarily sequential, though dependencies are obvious.
 - All stages must be addressed as relevant at outset of commitment to asteroid resource exploitation.
 - End-to-end plan must exist through all stages so that modifications may be made fluidly and that consequences of modifications become apparent downstream.
- Identify high-investment stages early, modify budgets accordingly.
- Adequately invest in knowledge/technologies that give high synergy with downstream operations.
- These ideas are not new.